Final Report for

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Rare Gas Excimer Emission from a Discharge Excited Supersonic Gas Expansion.

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Introduction

The research supported by ONR grant N00014-93-1-1050 was for the investigation of rare gas excimer emission from a discharge excited supersonic expansion. The discharge excited rare gas supersonic expansion is a possible vacuum ultraviolet (VUV) laser medium and also provides the ability to study rare gas diatomic molecules and clusters. VUV lasers would be useful in the photo-lithography of integrated circuits. The short wavelength of the rare gas excimer emission would allow the manufacture of circuits with at least four times higher element density. Rare gases have previously been used as the lasing medium for single-shot high power, VUV excimer laser systems. Unfortunately, this type of laser is not useful due to the inherent complexities of coupling a high energy electron beam into the high pressure gas vessel. The discharge excited supersonic expansion of rare gases offers a vastly simplified technique for forming the rare gas excimers. Additionally, rare gas molecules have not been thoroughly investigated.

This research was initiated at the Naval Research Laboratory, Laser Physics Branch while I was a National Research Council Postdoctoral Fellow. The research supported by Office of Naval Research was for a continuation and expansion of the research at the NRL. This program is to include determining laser feasibility using this system, determining the excimer formation processes, and mapping the excimer molecular states. Specifically, I proposed to construct the apparatus and investigate the excimer emission as a function of discharge electrode configuration, plenum pressure, and nozzle width. Further investigations were to include laser spectroscopy of rare gas molecules.

The proposal, "Rare Gas Excimer Emission from a Discharge Excited Supersonic Gas Expansion", was for a multi-year effort. The requested funding was for only the first year. During this first year I have concentrated on construction of the apparatus. Unfortunately, there have been some difficulties with the apparatus. At present, the discharge system and gas expansion system have been tested and break down of the gas can be achieved at the highest plenum pressures. The equipment necessary for the experiment has been purchased. The largest

delays have been writing the software necessary to control the data acquisition systems and getting sufficient plenum pressures in the nozzle, and the vacuum system for the detection system. In this report, I will detail what I have accomplished with the provided funding and what remains to be done to initiate the proposed research program.

Results of funding

The research proposed requires an extensive amount of apparatus. Most of this apparatus needed to be constructed "in-house". The apparatus can be broken into several distinct sub-systems. These are the vacuum chamber and expansion nozzle, the high voltage pulsed power supply, the vacuum ultraviolet detection system, and the diode laser systems.

Experimental Apparatus

a) Vacuum chamber and supersonic expansion nozzle.

The vacuum chamber was constructed using a 20 inch diameter bell jar collar. This provides a chamber with many observation ports to study the discharge. Two lids were manufactured to complete the chamber (see Fig 1). The vacuum chamber is currently evacuated to 50 mTorr.

The most important part of the experiment is the expansion nozzle. Previous research (at the NRL) has been hampered by having a fixed slit width, small nozzle (<1 cm). For the proposed research a long slit (~10 cm long) was desired. From my previous research I know that it is necessary to have a high pressure (above 1 ATM) in the expansion nozzle to observe emission on the second continuum excimer band of the rare gases. Previous work had used a small volume nozzle and a high throughput pulsed valve. For the supersonic expansion nozzle designed for this research, a single valve would not provide high enough gas flow to achieve the nozzle pressures desired. Three modified valves in parallel are used to provide sufficient gas for the system (see Fig. 2). Gas pressure in the nozzle as a function of gas pulse length has been directly measured and is shown in Fig. 3. The goal was to achieve a peak pressure of four atmospheres in 30 ms. We have been able to reach pressures of 4.6 ATM in 18 ms (4.6 ATM from approximately 50

mTorr). This provides sufficient gas pressure in the nozzle for the formation of excimer molecules.

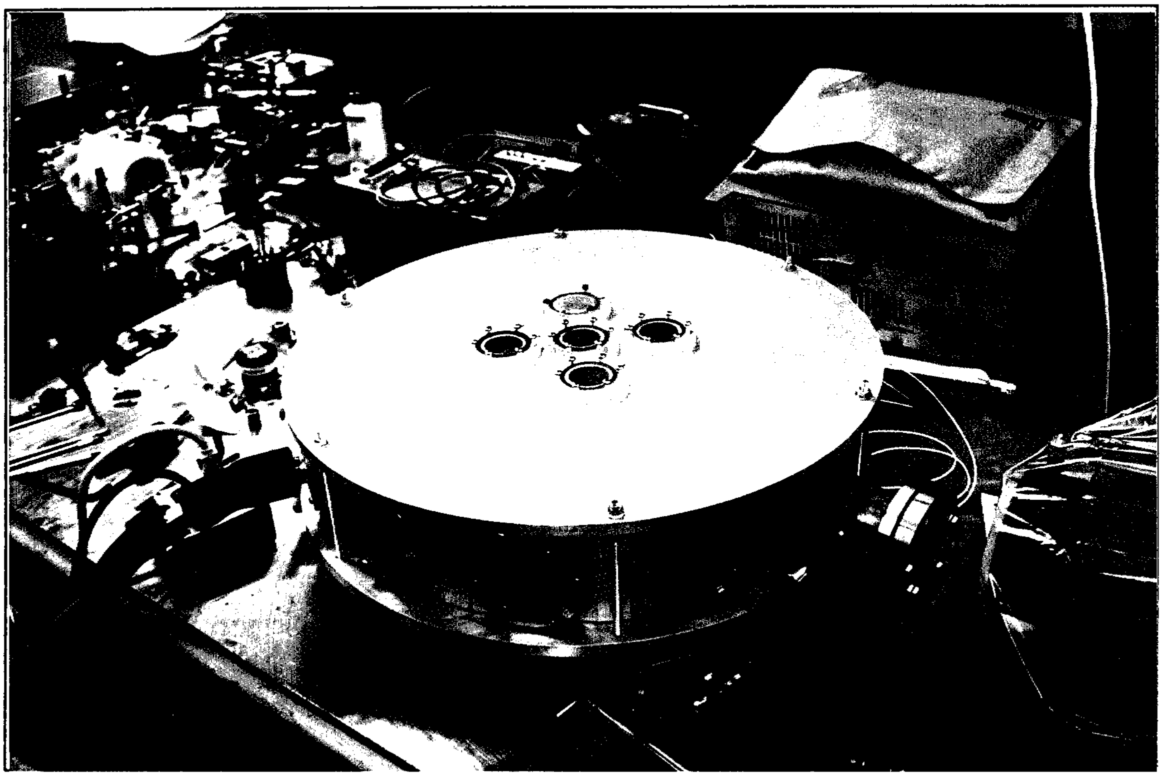

Figure 1. The vacuum chamber.

A second nozzle has been constructed for studying the emission inside the nozzle during a discharge. This has not yet been tested. In addition to being able to reach high pressures within the nozzle, the nozzles have been designed such that the nozzle slit width may be adjusted. The gas pressure for several slit widths is shown in Fig 3.

b) High voltage discharge system.

For the proposed research, a high voltage pulse ~100 ns long and ~30 kV peak voltage with ~1 kA of current must be produced. To do this I constructed a high voltage power supply which charges a capacitor bank to 30 kV. The capacitors are then discharged by a pressurized, triggerable spark-gap. This power supply has only been tested with capacitance's of 1 nF, 2.7 nF, and 8.1 nF. Under these conditions, the discharge current and voltage waveforms have a lot of ringing making it difficult to determine the FWHM of the current pulse.

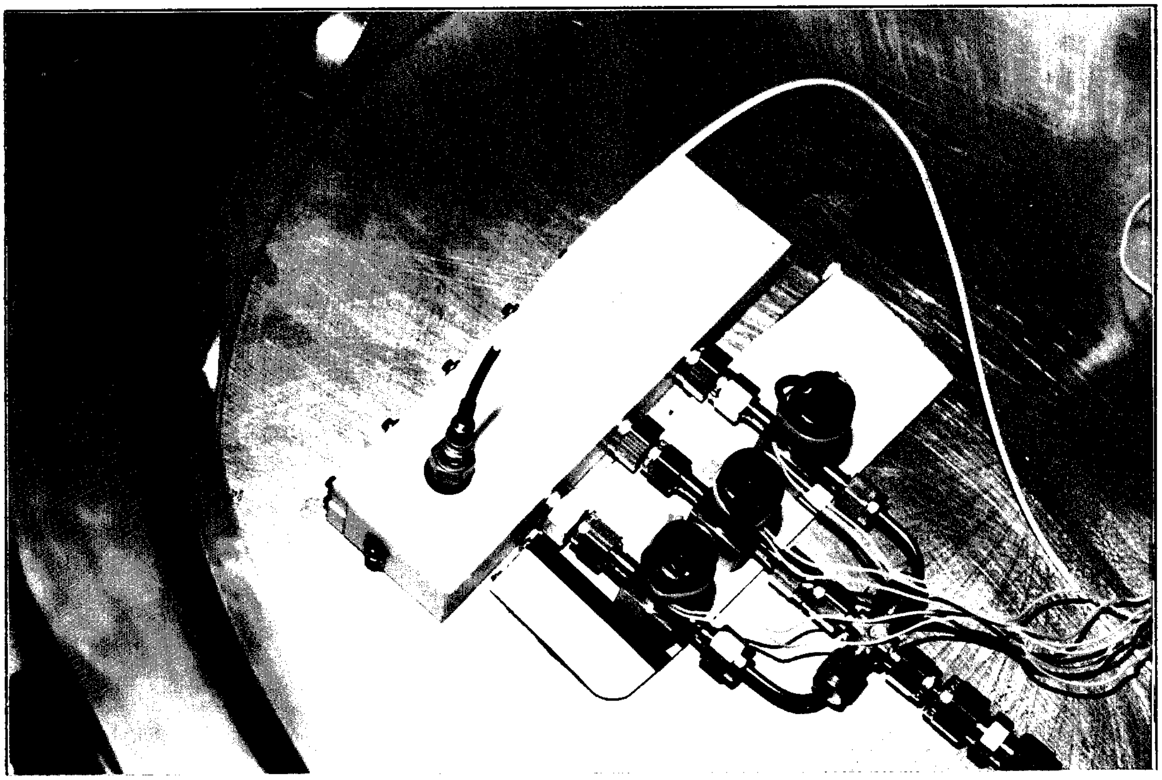

Figure 2. Supersonic Expansion Nozzle Assembly

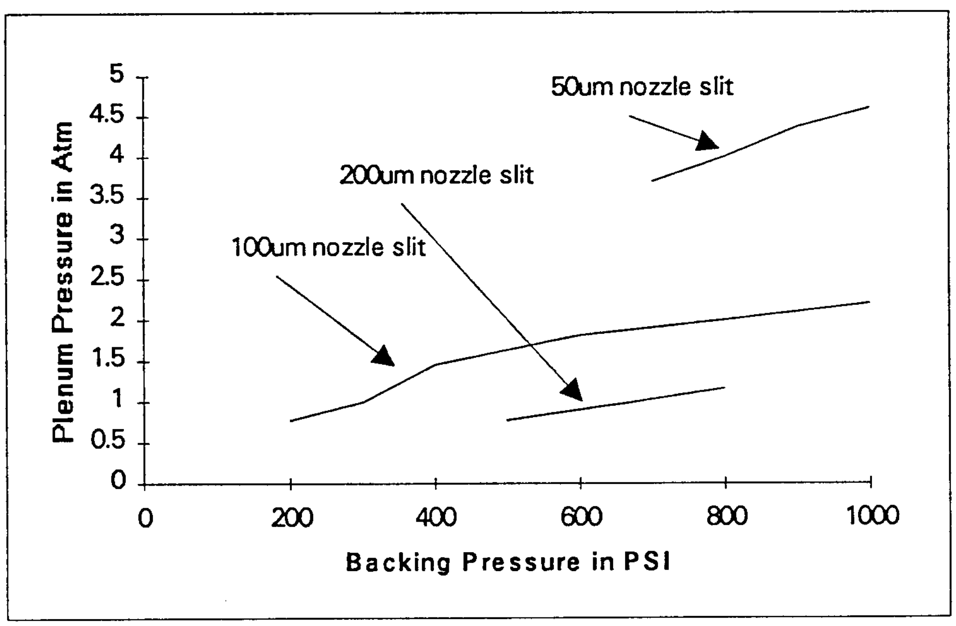

Figure 3. Peak Nozzle pressure as a function of line pressure

c) VUV detection system

The VUV detection system consists of a VUV monochromator which is to be evacuated to at least 10^{-5} torr. The previous vacuum system was a sorption pump and ion pump. These were not robust enough for our system and we are presently attaching a diffusion pump to the monochromator. The VUV emission is to be detected as a function of wavelength using the monochromator and a PMT coated with a scintillator material (or a VUV photodiode). The monochromator has been interfaced with the computer in order to ease data acquisition which can take upwards of five hours for a single scan.

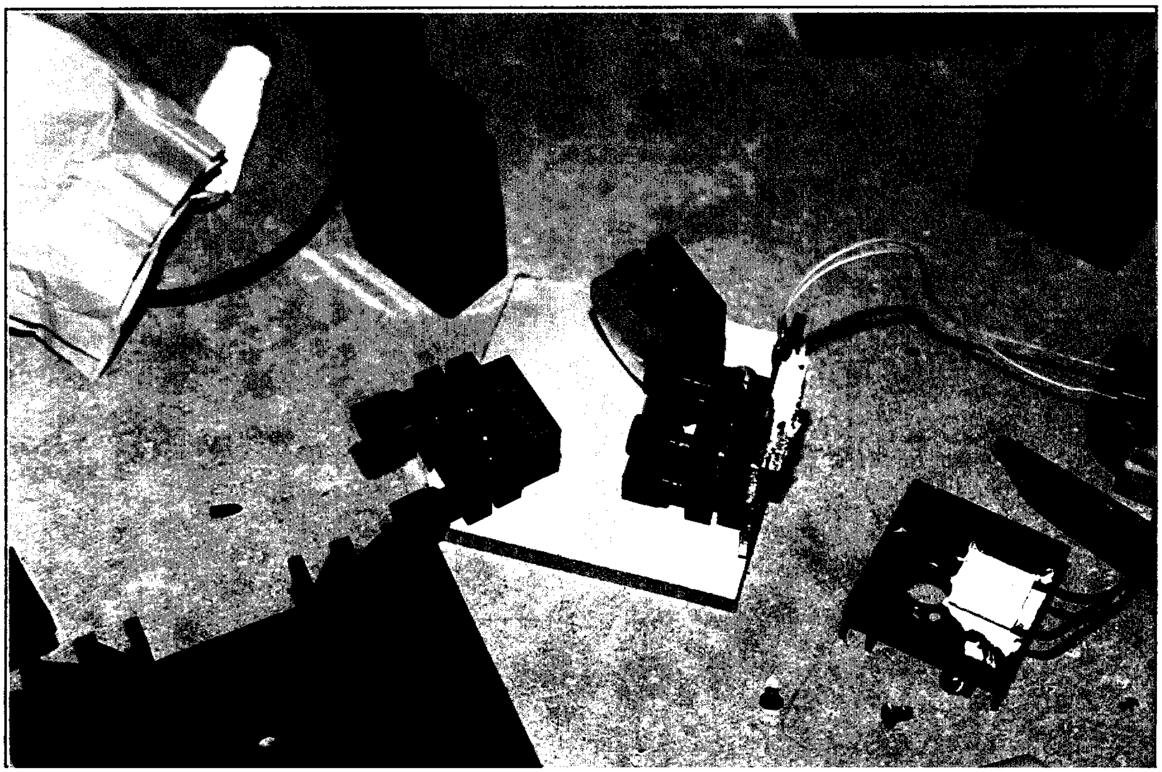

Figure 4. External Cavity of the Diode Laser system.

d) Diode laser system

To complete the proposed laser spectroscopy, we have constructed several external cavity diode laser systems at 780 nm, 810 nm, 830 nm, and 1.2 μm. We have designed and constructed precision current sources to power these lasers and precision temperature controllers to provide narrow bandwidth operation of the lasers. One of these lasers is now under operation and

materials are available for three others (see Fig. 4). One problem with the diode laser systems is the susceptibility to noise. The noise generated by the discharge can easily destroy a diode laser, or at a minimum can cause it to vary its frequency.

e) Other apparatus

To acquire the spectral and temporal information about the rare gas emission we have purchased a 1GSa/s oscilloscope. This oscilloscope is interfaced to the computer so that temporal data may be downloaded and stored. When the oscilloscope is operated in conjunction with the computer, it can act as a 10 channel, 10 gate digital boxcar averager. This is important for the acquisition of the excimer spectrum. The software interfacing the oscilloscope and monochromator to the computer has been written during the course of this funding year.

Experimental Results

We were only been able to take two spectra using the scintillator coated PMT before the monochromator vacuum system failed. One of these is shown in Fig. 5. This is a time integrated spectra using argon gas and shows some argon excimer emission. Fig. 5 indicates that the discharge excitation and the detection system function. Necessary improvements are the detection sensitivity, decreasing the vacuum chamber pressure to 10^{-4} Torr between gas pulses,

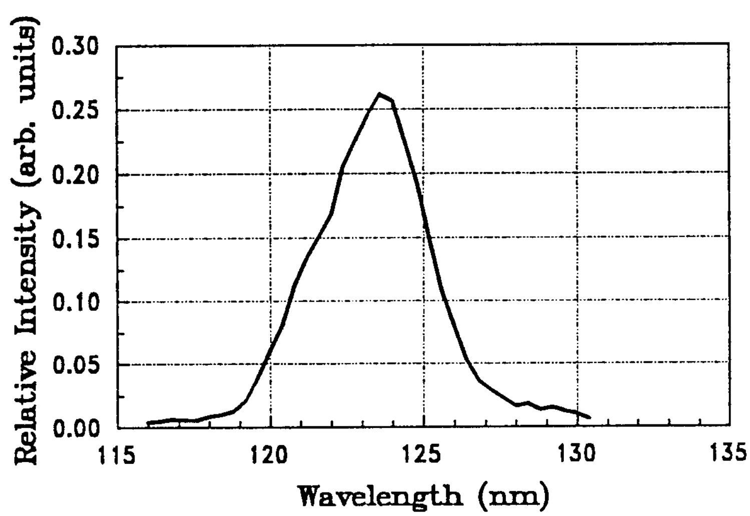

Figure 5. VUV spectrum

and providing a faster pump down to the 10^{-4} background pressure between pulses (to increase the data acquisition rate).

Conclusion

To improve the experimental system to increase the plenum pressure, improve the detection system and speed of data acquisition will require certain additional items. a turbo molecular pump for the vacuum monochromator, a small roots blower to increase the pumping speed of the chamber. In addition, a pulsed laser system, such as a Nd:YAG laser would be useful to replace the diode lasers.

During the past year I have been set up the apparatus for studying rare gas excimer emission from a discharge excited supersonic gas expansion. We have constructed the primary apparatus. This has included the design and construction of a vacuum chamber, several expansion nozzles and gas handling system, external cavity laser diode systems, and the design of interface software. I have completed each individual component of the system. The remaining work is to set up the new monochromator vacuum system and then start acquiring data.

I would like to thank the Office of Naval Research for providing the support to start this research program.